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(71) Applicant
Sony Broadcast & Communications Limited

(Incorporated in the United Kingdom)

Jays Close, Viables, Basingstoke, Hampshire, RG22 4BS, United Kingdom

(72) Inventors
Morgan William Amos David
Clive Henry Gillard
Martin Rex Dorricott
Ian Norman Sheldon

(74) Agent and/or Address for Service
D Young & Co
10 Staple Inn, London, WC1V 7RD, United Kingdom

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G03B 13/36

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H4D DLAE D711

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None

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INT CL⁵ G03G
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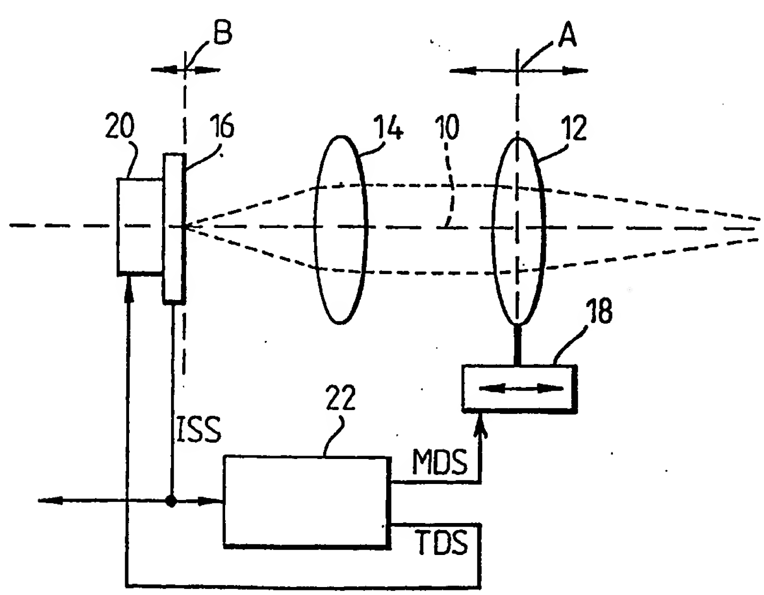
(54) Autofocus systems

(57) In an autofocus system for a camera provided with an image sensor 16 and a motor-driven 18 focussing lens 12, the image sensor 16 is mounted on a dither transducer 20 which receives dither oscillations TDS from a control circuit 22. The control circuit 22 also provides a motor drive signal MDS to move the focussing lens 12. The image sensor 16 is physically oscillated along the optical axis 10 at a rate less than field rate, but fast enough for the resulting out-of-focus movements not to be perceivable. The control circuit 22 responds to high-frequency information in the image signal ISS to set the focussing lens 12 at a position such that the high-frequency information is maximised within the range B of the physical dither provided by the transducer 20. Once optimum focus has been reached, the TDS signal can be used to check focus continuously whilst leaving the focussing lens 12 stationary.

FIG. 1.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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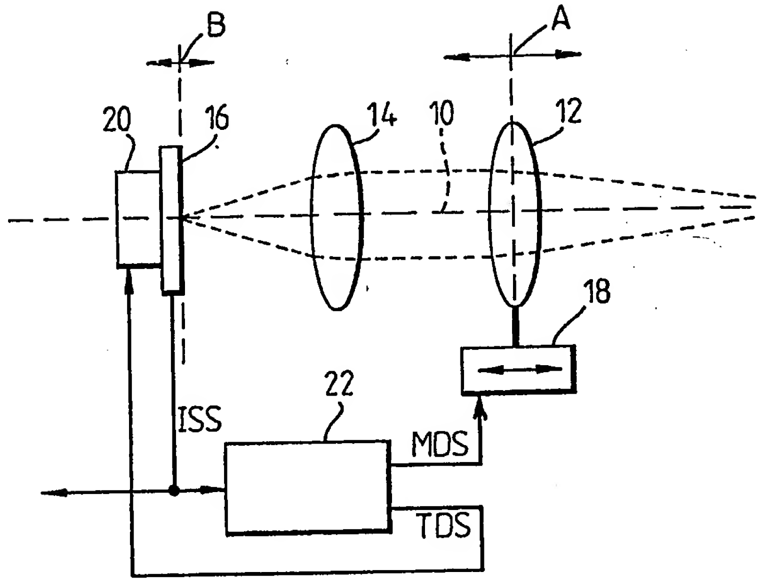
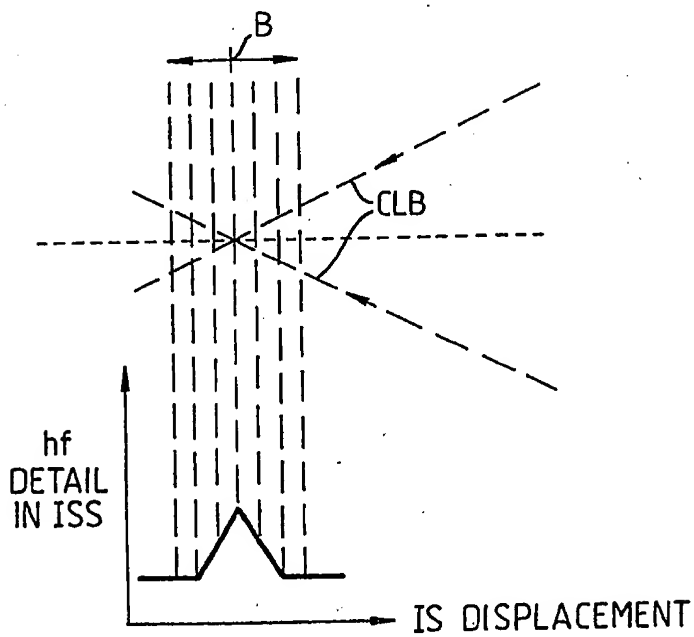
FIG. 1.



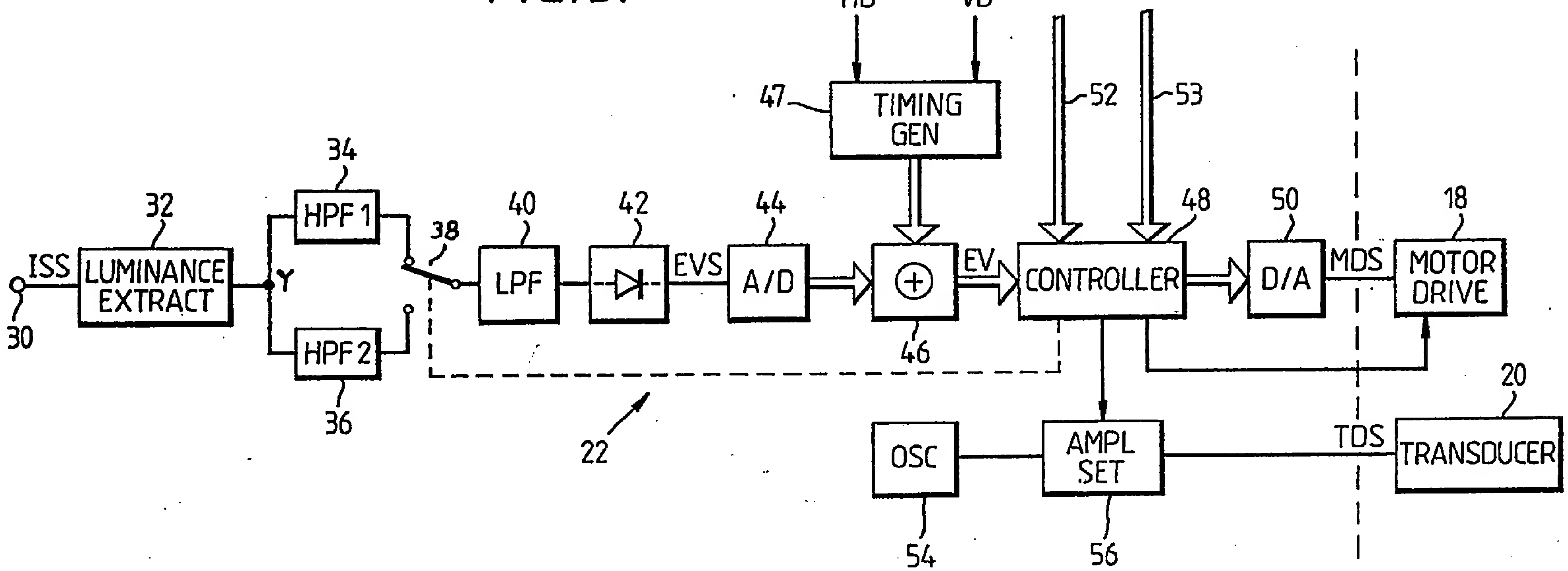
B
A
20
16
14
10
12
18
22
ISS
MDS
TDS

FIG. 2.



B
CLB
hf
DETAIL
IN ISS
IS DISPLACEMENT

FIG. 3.



30
ISS
32
LUMINANCE EXTRACT
Y
34
HPF 1
36
HPF 2
38
40
LPF
42
EVS
44
A/D
47
TIMING GEN
HD
VD
46
EV
52
53
48
CONTROLLER
50
D/A
MDS
18
MOTOR DRIVE
22
OSC
54
AMPL SET
56
TDS
20
TRANSDUCER

AUTOFOCUS SYSTEMS

This invention relates to autofocus systems for cameras such as video cameras.

It is known for so-called passive autofocus systems provided in video cameras such as domestic camcorders to sense correct focus by analysing high-frequency detail in the image. It can be shown that an image which has been optimally focussed has a maximum of high-frequency information such that there is a reduction in such high-frequency information when the image is defocussed in one direction or the other. A video camera thus includes a motor for driving a focus ring on the lens until a maximum of detail is sensed, in other words until high-frequency information in the image is maximised. When the camera is out-of-focus, such as when first switched on or following a change of scene, the lens may start a focus search operation from one or other of the focus limit positions, namely either infinity or closest possible distance to the lens. The set focus is then changed so as to scan over the focus range by driving the focus ring motor until a high-frequency maximum is detected. For this to be possible, the focus ring must overshoot correct focus slightly so that a change from increasing to decreasing high-frequency information can be detected. The focus ring motor then corrects the focus ring position for optimum focus. However, once sharp focus has been achieved, it is necessary to check periodically whether focus is still correct. This may be done by, at regular intervals, driving the lens very slightly out of focus firstly in one direction then in the other. This operation will check for the continued presence of the high-frequency maximum and, if this is found to be no longer within the focus check range, the lens will revert to the focus search operation.

In view of the electro-mechanical nature of the above-described system, and the inertia to be overcome in driving the focus ring, the periodic focus check operation is comparatively slow, typically taking about one second to complete. This can cause a noticeable disturbance to the sharpness of the picture, and also result in the presence of some mechanical noise. The loss of sharpness is particularly noticeable in low light level conditions when correct focus is less easy to establish, thus causing more frequent adjustments of the lens

servo. Also, when the lens is zooming, the focus system needs to respond rapidly if it is to remain in focus. If focus is lost, the system must commence the focus search operation which involves further image disturbance. Such rapid response of the focus system is not readily achievable with the inertial effect of the lens focus motor drive.

According to the invention there is provided an autofocus system for a camera provided with an image sensor and a motor-driven focussing means, the autofocus system comprising:

oscillating means operable to provide a physical dither causing the image at the image sensor to change its focus state in accordance with the physical dither; and

control means for driving the oscillating means and the motor-driven focussing means, the control means responding to high-frequency information in an image signal from the image sensor to set the focussing means at a position such that the high-frequency information is at a maximum within the range of the physical dither provided by the oscillating means.

In a preferred embodiment of the invention, described more fully below, the autofocus system includes a linear transducer such as a piezo-electric crystal or a speaker coil arranged to oscillate the image sensor rapidly along the optical axis of the lens system, at a rate much less than the field rate of 50 Hz or 60 Hz, but sufficiently fast to ensure that the eye can integrate any otherwise perceivable de-focussing effects; thus the out-of-focus oscillations do not cause a noticeable disturbance to the image. The rapid oscillations allow the detail sharpness of the image to be continuously monitored over a small range of different focus positions. From this, it is possible to derive a signal to drive the lens focus servo in the correct direction for optimum sharpness. Once optimum sharpness has been reached, this signal can be used to check focus continuously without further movement of the lens focus ring. The lens focus ring is moved only when it is predicted that the focus state is changing sufficiently to move out of the limited range provided by the dither oscillation control.

In the preferred embodiment, it may be of advantage, when optimum focus has been found, to reduce the amplitude of the dither oscillations to a level at which the focus maximum can just be

detected, thereby saving energy and minimising any disturbances to the picture.

Providing that the focus maximum is kept within the range of the dither oscillation by operation of the lens focus servo, it is possible to use a linear control loop which in turn brings benefits in terms of speed of response of the focussing system. If the maximum is lost, the focus servo will need to be used to scan the focus range to regain sharp focus. However, the use of dither will give advance warning of a return to sharp focus, allowing a return to linear control of the loop and thus preventing overshoot of the lens focus servo.

When the autofocus system is used in a three-imager (red, green, blue) colour camera, the focus dither can be applied to the green imager only, since the green signal contributes most of the luminance content of the image normally associated with its sharpness.

In order to improve focus performance when the zoom servo is operated, it may be beneficial to control the area of the image analysed for high-frequency detail, particularly when zooming from wide to telephoto states. In such a case, the focus system should concentrate on the central portion of the picture only, since this portion is about to expand and fill the frame. This measure allows the focussing system to predict the general area of interest by sensing the direction of zoom.

The preferred embodiment thus has the advantages of improved tracking of focus, since the dither allows predictions to be made about the direction and speed of focus change, of less disturbance to the image since regular visible movements of the lens focus ring are not necessary, and of reduced power requirements since, in general use, the dither oscillations will require less power than would regular lens motor movements.

The invention will now be described by way of example with reference to the accompanying drawings, throughout which like parts are referred to by like references, and in which:

Figure 1 is an outline schematic view of an autofocus system according to an embodiment of the invention;

Figure 2 is a graphical representation of the focussing operation of the autofocus system of Figure 1; and

Figure 3 is a block diagram of a more detailed implementation of

the autofocus system shown in Figure 1.

Referring to Figure 1, an autofocus system according to the preferred embodiment of the invention is shown in outline schematic form. The optical parts of the system are disposed along an optical axis 10 and include a focussing lens element 12, a rear lens element 14, and an image sensor 16 such as a charge-coupled-device (CCD). The focussing lens element 12 is movable along the optical axis 10 by a lens motor drive 18, the directions of movement being shown by an arrow A. The image sensor 16 is shown as being mounted on a dither transducer 20 which provides a limited range of movement along the optical axis 10, as shown by an arrow B. The image sensor 16 provides an image sensor signal ISS for further processing by the video circuitry (not shown) and which is also supplied to a control circuit 22. The control circuit 22 processes the image sensor signal ISS and, on the basis of such processing, produces two autofocus output signals, namely a motor drive signal MDS supplied to the lens motor drive 18, and a transducer drive signal TDS supplied to the dither transducer 20.

The operation of the autofocus system shown in Figure 1 will now be described in outline. The transducer drive signal TDS is an oscillating signal having a frequency much less than the field rate of the image signal (50/60 Hz) but sufficiently rapid to ensure that its de-focussing effect on the image sensor 16 is not perceivable by the eye, in view of the eye's integrating effect of rapid variations in an image. The frequency of the transducer drive signal TDS can typically be in the order of 10 Hz. The dither transducer 20 can be of any form capable of providing a dither movement to the image sensor 16 along the optical axis 10 in response to the transducer drive signal TDS. A suitable form of transducer is a piezo-electric element or an electro-magnetic transducer such as a speaker coil.

Focus search in the system of Figure 1 is achieved by the control circuit 22 providing a motor drive signal MDS to the lens motor drive 18 such that the focussing lens element 12 scans across the focussing range A of the lens system. While this is in progress, the transducer drive signal TDS is providing physical dither to the image sensor 16 by means of the dither transducer 20. The image sensor signal ISS from the image sensor 16 is continuously analysed by the control circuit 22. As the focussing lens element 12 is being moved, comparatively slowly,

through the focussing range, the focussing state of the image sensor 16 is being continuously varied, at a much faster rate, by the dither transducer 20. The control circuit 22 (as will be explained in more detail below) analyses the high-frequency information in the image sensor signal ISS and, when this is found to be a maximum, sets the focussing lens element 12, by means of the lens motor drive 18, to the optimum position. Although this part of the operation is broadly similar to that of the above-described previously-proposed autofocus system, there is a difference in that the correct focus position will be detected slightly earlier. This is because, although the focussing lens element 12 has not quite reached the optimum position, the superimposition of physical dither on the image sensor 16 will allow correct focus to be detected near the amplitude limits of the oscillations of the dither transducer 20. Thus correct focus is determined and the focussing lens element 12 can be moved so that the correct focus state corresponds to the mid-point of the oscillations of the dither transducer 20. Thus there is no need for the focussing lens element 12 to "overshoot", as in the previous system, since the dither transducer 20 provides a similar effect without the substantial disadvantage of having to reverse the direction of the focussing lens element 12.

Figure 2 is a graphical representation of detection of the optimum focus. The relationship between the image sensor IS displacement against the high-frequency detail in the image sensor signal ISS can be seen, with reference to the convergent light beam CLB provided by the optical system including the focussing lens element 12 and the rear lens element 14. It will be seen that, over the range of movement B provided by the dither transducer 20 to the image sensor 16, the convergent light beam CLB provides a maximum of high-frequency detail at the mid-point of the image sensor 16, the high-frequency detail falling off on either side of the peak. This will represent the normal operating point of the system, once the focus search operation has been completed as described above. That is, the control circuit 22 will tend to move the focussing lens element 12 (by means of the lens motor drive 18) so as to centre the correct focus position of the convergent light beam CLB at the mid-point of dither movement of the image sensor 16. It will be apparent from Figure 2 that, if the focus

state starts to change, the control circuit 22 will be readily able to detect the direction of change by means of detected movement of the peak position of the high-frequency detail, and the focussing lens element 12 can be moved accordingly. This provides greatly improved control of the autofocus state, since the dither oscillations effectively provide a window of movement of focus position which is continuously being monitored so that corrective movement of the focussing lens element 12 can be initiated as soon as it is necessary. The window effect of the dither oscillations can also be used to provide a degree of hysteresis in the system to prevent excessive small movements of the focussing lens element 12. Thus, it can be arranged that, as long as the focus change does not move too far over the range defined by the arrow B, the focussing lens element 12 will not be moved unless that new focus state is maintained for longer than a predetermined time. Thus limited distance back-and-forth movements in the image will not result in constant re-adjustments of the focussing lens element 12, as long as those movements are within the range B of the dither oscillations applied to the image sensor 16.

Figure 3 shows a block diagram of one implementation of the control circuit 22 of Figure 1. An input terminal 30 receives the image sensor signal ISS from the image sensor 16, and supplies it to a luminance extraction circuit 32. The luminance component of the image sensor signal ISS is extracted by the luminance extraction circuit 32 and forms a luminance signal Y applied to the inputs of first and second high-pass filters (HPF) 34 and 36. The outputs of the HPFs 34 and 36 are selected by a selector switch 38 and then supplied, via a low-pass filter (LPF) 40, to a half-wave rectifier circuit 42. The half-wave rectifier circuit 42 produces an evaluation value source (EVS) signal which is supplied to an analogue-to-digital converter 44. The digitised EVS signal is supplied to a digital full adder 46 which acts as an integrator, as will be explained below. A timing generator 47 receives horizontal and vertical timing signals HD and VD from the video processing circuitry, and supplies its output to the digital full adder 46. The output of the digital full adder 46 constitutes an evaluation value (EV) signal which is used for autofocus control. The EV signal is supplied to a controller 48, preferably in the form of a microprocessor. The controller 48 calculates the optimised focussing

conditions and supplies a digital signal to a digital-to-analogue converter 50, as a result of which the motor drive signal MDS for the lens motor drive 18 is provided. The controller 48 also receives a manual focus override input 52 which inhibits autofocus control and sets the focus according to the signal provided on the manual focus override input 52, when manual focus control is required by the camera operator. A zoom control input 53 supplies the controller 48 with data relating to the zoom state of the lens system.

The control circuit 22 also includes a dither oscillator 54 (which can, as stated above, be set to about 10 Hz) and an amplitude set circuit 56 which responds to the controller 48 to provide the transducer drive signal TDS to the dither transducer 20.

The controller 48 also sets the state of the selector switch 38.

The operation of the control circuit 22 shown in Figure 3 is as follows. The image sensor signal ISS from the image sensor 16 is supplied, via the input terminal 30, to the luminance extraction circuit 32. The resulting luminance signal Y is supplied via either one of the first and second HPFs 34, 36 (depending on the setting of the selector switch 38) to the half-wave rectifier circuit 42 via the LPF 40. The high-frequency components of the luminance signal Y are extracted by whichever of the first and second HPFs 34, 36 has been selected, and, once these high-frequency components have been rectified by the half-wave rectifier circuit 42, the evaluation value source EVS signal is generated. This signal will be dependent on the amount of high-frequency information in the luminance component of the image sensor signal ISS.

A digitised version of the EVS signal is supplied to the digital full adder 46 acting as an integrator. The timing generator 47 is operable to limit the extent of the image that is used for autofocus control. Thus, only a central portion of the image can be selected for autofocus control, if desired, this central portion being defined by the timing signals HD, VD, and the digital full adder 46 will be gated so as to add only the EVS signals from that central portion. Thus the integration operation of the digital full adder 46 will be limited to the required area by the timing generator 47.

At a required interval, such as every field, the integrated value of the EVS signals over that field, or at least over the required part

thereof, is supplied as the evaluation value EV signal to the controller 48. The EV signal represents the data necessary for automatic focus control, since the EV signal will be a maximum when the optical system is in focus.

The controller 48 receives a series of EV signals representative of different positions of the image sensor 16 (as oscillated by the dither transducer 20). The preferred algorithm of the controller 48 is, as shown in Figure 2, to hold the maximum EV signal at the mid-point of the range of movement of the image sensor 16. Thus, if the EV signal maximum is not at the mid-point, a signal will be sent to the digital-to-analogue converter 50 to provide a motor drive signal MDS for adjustment of the focussing lens element 12 so as to set the EV signal maximum to the required mid-point. However, as discussed above, the controller 48 can subject such focussing lens movement to a time constant delay such that, for example, only a rapid EV signal maximum movement and/or a signal movement near the limit of oscillation provided by the dither transducer 20, will result in a motor drive signal MDS to the lens motor drive 18.

The selector switch 38 is shown as being under the control of the controller 48. The first and second HPFs 34, 36 have different filter characteristics, and the controller 48 can select which is to be operable at any moment; for example, a different high-frequency characteristic may be appropriate during focus search, compared to that in the autofocus state.

The amplitude set circuit 56 for the dither oscillator 54 is also shown as being responsive to the controller 48. This can provide an advantageous feature in that, when optimum focus has been found, the amplitude of dither oscillations may be reduced to a level at which the focus maximum can still just be detected. This will save power and also minimise any disturbance to the picture. Once the controller 48 detects a substantial change in focus, the amplitude set circuit 56, which may be a variable gain amplifier, can be made to provide larger amplitude oscillations again. Alternatively, or in addition, the amplitude set circuit 56 may be arranged to cut off oscillations to the dither transducer 20 for regular periods. It may be found that, in certain circumstances, it is unnecessary to oscillate the image sensor 16 continuously, and if this is the case, further power can be saved by

this measure.

It is preferred that the dither transducer 20 operates in a linear fashion, since this allows the use of a linear control loop which brings benefits in terms of speed of response of the focussing system. The above advantage of not necessarily requiring the optimum focus position to be always at the mid-point of the dither oscillations can therefore be obtained. However, it would be possible to use a non-linear transducer if this advantage were not required.

In a colour video system, the luminance signal Y can be obtained from the three colour (red, green and blue) signals. However, in a simpler system, the luminance component of only one signal can be used. The green signal generally contributes most to the luminance content of the image normally associated with the sharpness of the image, and this would therefore be the preferred signal to use in such circumstances. Similarly, in a three imager system, the focus dither could be applied only to the green imager since this would provide a better defined evaluation value signal than dither applied to the red or blue imagers.

The timing generator 47 has been described as defining the portion of the image over which the evaluation value is calculated (and therefore on which focussing control is dependent). Rather than using a fixed portion of the image, focus performance can be improved during zoom operations by controlling the area of the image analysed for high-frequency detail, particularly when zooming from wide to telephoto settings, on the basis of data supplied to the controller 48 from the zoom control input 53. In such a case, the focus system should be arranged to concentrate on only a predetermined central portion of the picture as it is about to expand and fill the frame. By sensing the direction of zoom, the focussing system could be made to predict the general area of interest. In a similar manner, when zooming down to wide angle setting, the area of the image set by the timing generator 47 could be opened up in advance of completion of the zoom operation.

In the above embodiment, the dither oscillations have been described as being applied directly to the image sensor 16, such as by physically mounting the image sensor 16 to the dither transducer 20. Whereas this is a preferred arrangement and has various advantages, it is possible that a similar effect could be achieved by applying the dither oscillations remotely. For example, the dither oscillations

could be applied to a lens element of the lens system, rather than to the image sensor itself, and this would provide a similar effect. However, from the point of view of optical system design, it is believed to be simpler and more practical to oscillate the image sensor directly. The signal processing is then more predictable and, moreover, the possibility of using interchangeable lens systems (unencumbered by the need to provide an oscillating lens element) is increased.

CLAIMS

1. An autofocus system for a camera provided with an image sensor and a motor-driven focussing means, the autofocus system comprising:

oscillating means operable to provide a physical dither causing the image at the image sensor to change its focus state in accordance with the physical dither; and

control means for driving the oscillating means and the motor-driven focussing means, the control means responding to high-frequency information in an image signal from the image sensor to set the focussing means at a position such that the high-frequency information is at a maximum within the range of the physical dither provided by the oscillating means.

2. An autofocus system according to claim 1, wherein the oscillating means is operable to provide a physical dither directly to the image sensor along the optical axis of the camera.

3. An autofocus system according to claim 2, wherein the oscillating means comprises a transducer to which the image sensor is coupled.

4. An autofocus system according to claim 3, wherein the transducer is a piezo-electric transducer.

5. An autofocus system according to claim 3, wherein the transducer is an electro-magnetic coil.

6. An autofocus system according to any one of the preceding claims, wherein the control means is operable to drive the motor-driven focussing means such that the maximum of the high-frequency information tends to be set at the midpoint of the physical dither oscillations provided by the oscillating means.

7. An autofocus system according to any one of the preceding claims, wherein the control means is operable to vary the amplitude of the physical dither provided by the oscillating means.

8. An autofocus system according to claim 7, wherein the amplitude of the physical dither is relatively high during a focus search operation, and is relatively low during a focus tracking operation.

9. An autofocus system according to any one of the preceding claims, wherein the control means includes a high-pass filter for extracting high-frequency components from the image signal, and rectifying means for providing a high-frequency component indicative signal.

10. An autofocus system according to claim 9, including an integrating means for integrating the high-frequency component indicative signal to provide an evaluation signal for peak detection.

11. An autofocus system according to claim 10, wherein the integrating means is operable to integrate the high-frequency component indicative signal only over a predetermined area of the image.

12. An autofocus system according to any one of the preceding claims, wherein the image sensor is in the form of a three imager colour system, and wherein the physical dither is applied to only one of the imagers of the three imager system.

13. An autofocus system according to claim 12, wherein the three imager colour system is a red-green-blue system, and wherein the physical dither is applied to the green imager only.

14. An autofocus system for a camera provided with an image sensor and a motor-driven focussing means, the autofocus system being substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

15. A camera provided with an autofocus system according to any one of the preceding claims.

- 13 -

atents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number 9116121.6

Relevant Technical fields

(i) UK Cl (Edition K) H4D (DLAE)

(ii) Int Cl (Edition 5) G03B

Search Examiner

R F KING

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASE:WPI, INSPEC

Date of Search

10 OCTOBER 1991

Documents considered relevant following a search in respect of claims 1-15

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
	NONE	

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Category	Identity of document and relevant passages	Rele t to claim(s)

Categories of documents

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